or south at the time of the equinoxes, the skylight is plane polarized horizontally. Between the zenith and the horizon it is plane polarized at varying angles, except at two points which range from 15° to 25° above the horizon where the polarization is zero.

Therefore at noon during the summer season, the amount of polarization near the horizon to the west enables one to isolate from the haze incipient thunderheads considerably in advance of their detection with the naked eye. Near the sun, where polarization is slight and the diffused light intense, clouds are better detected with a dense red filter than with a Nicol prism.

In practice one does not *compute* the angle of polarization, but merely adjusts the Nicol by orientation until the sky appears darkest at which point the *plane* of the Nicol is at right angles to the plane of polarization. Through a perfect Nicol a cloud in a sky 100 percent polarized would appear snow-white against a jet-black background. Such contrasts never occur in nature, however, as the percentage of skylight polarization rarely exceeds 80. As even the inconsiderable amount of polarized light from the cloud is chiefly elliptical, the Nicol is of little use as an analyzer of its illumination.

SUPERSATURATION AGAIN

By W. J. HUMPHREYS

[Weather Bureau, Washington, November 1933]

Most of us well may wonder whether the persistent idea that a fourfold supersaturation can and does occur in the air is Truth, for crushed to earth it rises again, or a Hydra which every time its head is cut off sprouts two new ones in its stead. At any rate it keeps bobbing up here, there, and yonder, even in scientific literature—in the offhand explanation of a cloudburst (excessively heavy local rain), perhaps; the boiling of a large cumulus, or cumulonimbus, cloud; or some other such meteorological phenomenon which the author has not taken the trouble to understand.

By saturation is meant that degree of humidity, or mass of water vapor per unit volume (vapor density), that is, or would be, in equilibrium with a flat surface of pure water at the same temperature. Supersaturation is any higher degree of humidity, or greater vapor density, than that of saturation. Now from observation, and by experiment, we know that in ordinary air condensation, producing a fog of water droplets, starts when the humidity is in the neighborhood of saturation—more or less short of saturation when the condensation nuclei are particles of sea salt or other hygroscropic substance, and slightly beyond, perhaps, when they are nonhygroscopic. In well-filtered air, on the contrary, condensation does not begin until at least a fourfold supersaturation is attained and then only on such negative ions as may be present. A much greater supersaturation is necessary to cause condensation on positive ions, and a greater still in the case of neutral molecules. Therefore, in order that any considerable degree of supersaturation may occur in the atmosphere it must be freed from all ordinary condensation nuclei.

Our discussion, therefor, may be divided into two distinct parts—(1) a consideration of whether any large volume of the troposphere, or rainy region of the atmosphere, can be freed of condensation nuclei; and (2) what would happen if condensation should occur in a fourfold supersaturated space of considerable size. We need not concern ourselves about providing negative ions—they appear to be always and everywhere in the atmosphere.

Is, then, any considerable volume of the troposphere ever free from condensation nuclei? This much we can say: All the innumerable examinations for such nuclei, under various weather conditions and at many different levels, showed them to be present in great abundance. To be sure we can free a small volume of air from nuclei by filtering it, for example, through a tube filled with raw cotton, glass wool, or other finely divided suitable substance; and by inducing repeated condensations in it by expansions, say in a bell jar containing some water, and allowing the droplets to settle out carrying the nuclei with them. But the free air is not operated on very completely in either of these ways. The nearest approach to exhaustion of these nuclei in the open air presumably occurs in the midst of a large nimbus or cumulo-nimbus cloud. Here the ascending nucleus-laden air is partially filtered as it rises through the cloud, and partially cleaned by progressive condensation. Even if the air within any portion of the cumulus were freed from all nuclei there still would be droplets, or snow crystals, falling through it from its outer shell, as it were, which is in contact with unfreed air, and any considerable supersaturation thus prevented. And, of course, it could not pass out through this wall of dense cloud, every droplet of which is an efficient condensation nucleus, and still remain appreciably supersaturated. Presumably, therefore, marked supersaturation does not occur in the open atmosphere.

However, let us assume that sometimes a considerable volume of the air is cleared of all ordinary condensation nuclei, and that supersaturation has progressed to the fourfold value, at which stage condensation begins on the ever present negative ions. What would happen?

Condensation once begun would progress with great rapidity on the droplets thus formed until the vapor density had fallen to normal saturation. The freed heat of vaporization would increase the temperature of the air, expand it and induce convection, which in turn would cause the condensation of more vapor and further convection to a great but determinate height. Here a little calculation will be helpful, and rough approximations will suffice.

Let, then, the temperature of the air be 25° C., or 298° absolute, and the saturation fourfold, and let condensation start at this stage.

According to humidity tables the initial vapor density would be 91 grams per cubic meter. Density of the air, 1,200 grams per cubic meter, roughly. Specific heat of air at constant pressure, allowing for the water vapor present, 0.25, approximately. Latent heat of vaporization, say 600 calories per gram.

Hence to warm the 1,200 grams of air 1° C. would require 300 calories, which could be supplied by the condensation of 0.5 gram of vapor. But this warming would expand the air and correspondingly increase the volume to be occupied by the vapor.

Let the initial condensation from a fourfold supersaturation to normal saturation, and the consequent heating and expansion, occur at constant pressure, that is, be complete before convection sets in.

Let x° C. be the increase in temperature and y the grams of vapor condensed. Then

$$x = 2y$$

$$\frac{\text{New volume}}{\text{Old volume}} = \frac{298 + x}{298}$$

91 = initial grams per cubic meter.

$$\frac{91 - \frac{x}{2}}{\frac{298 + x}{298}} = \text{final grams of vapor per cubic meter.}$$

We can assume any value we like for x and compute from the last equation the corresponding vapor density. If this value is too great for normal saturation at the absolute temperature $298 + x$ then x is too small; and conversely, when the computed value is less than that required for saturation. In this way an approximately correct value of x is readily determined.

It turns out that, under the assumed conditions, namely, fourfold supersaturation at 25° C. $x = 22°.5$.

Vapor condensed, $y = \frac{x}{2} = 11.25$ grams per initial cubic meter, leaving 79.75 grams per initial cubic meter uncondensed.

Violent convection will occur, owing to the great heating, and continue until very little vapor is left. As a rough approximation let all the water vapor be condensed. The heating would be $x = 2y$, but y is 91, the initial grams per cubic meter. Hence $x = 182°$ C., and the temperature would be 207° C. This would cause the air to ascend into the stratosphere, and to reach the temperature of this region, say $-53°$ C., the cooling would need to be 260° C., and the ascent, if along the dry adiabat, 26 kilometers. Actually the condensation and resulting cumulus cloud would be all along the route of ascent.

But cumulus clouds of such great heights have never been observed.

The conclusions are:

1. It does not appear possible for any appreciable supersaturation to occur in the atmosphere, much less a fourfold supersaturation that would be necessary to condensation on negative ions.

2. The inevitable consequences of such a supersaturation are not known to occur.

Presumably, therefore, such supersaturation does not and cannot occur in the free air. Presumably also the unwarranted assumption that it does so occur still has a long lease of life in our scientific literature and even immortality in popular writings.

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